

**Radio Frequency Weapons (RFW) Detection,
Characterization and Effects RDT&E in a Large-Scale
Installed System Test Facility (ISTF)**

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Introduction

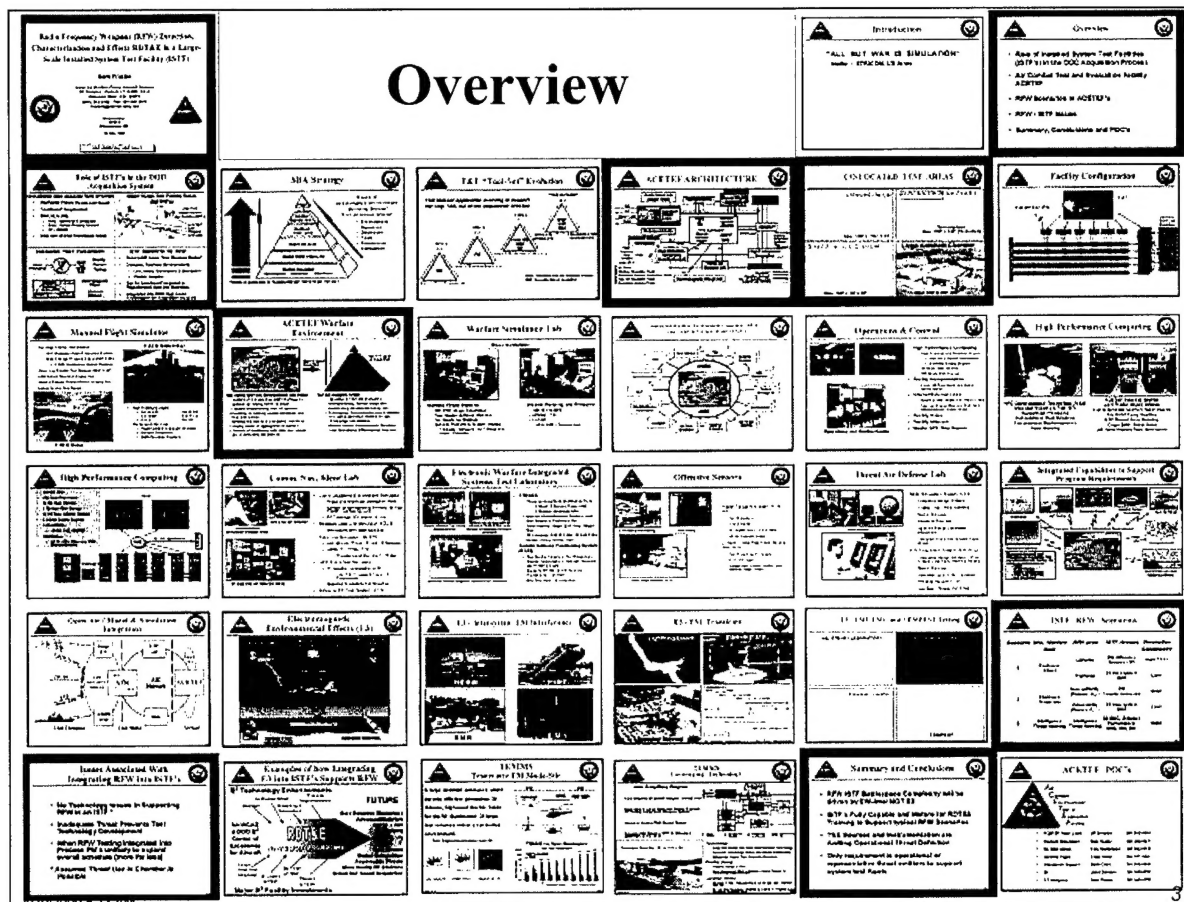


“ALL BUT WAR IS SIMULATION”

motto - STRICOM, US Army

All but war is simulation. That is a pretty powerful statement.

I prepared this presentation assuming that the anechoic chamber at PAX was a great place to perform testing because of the available high-level laboratory support. But the chamber isn't an end, it's a means. We are entering a new paradigm in the acquisition process. Most of you are involved in Defense acquisition. I am a tester, our goal is production testing to fully integrate assessments into the acquisition process as a repetitive, almost transparent process.



You can all say you saw my entire brief,.....all 34 slides.

This is the brief I have entered into the conference proceedings, I will present the highlighted slides to summarize this topic. I encourage you to review the complete presentation when you receive the proceedings.

•The Overview

We will begin with an overview of the DOD acquisition system and identify ISTF's role in the DOD RDT&E infrastructure.

I will provide an overview of the ISTF located at Patuxent River, MD, I will quickly identify the laboratory teams and facilities that make up this unique capability.

The highest Level of complexity capable in our ISTF will be shown, to illustrate how powerful they are and how they contribute to the overall DOD Modeling and Simulation RDT&E and Training effort.

As you can see all detail about the laboratory is being left as a homework assignment.

We will take a quick look at the 3 general RFW scenarios you would conduct in an ISTF.

Based on these scenarios we will identify some issues and observations about RFW testing in an ISTF.

I will close with brief summary and conclusions



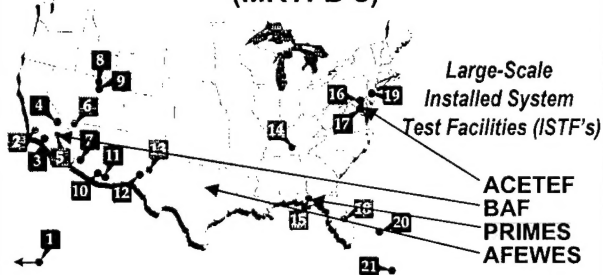
ISTF's in the DOD Acquisition System



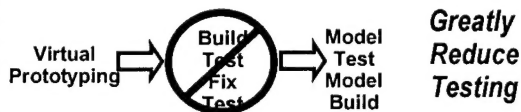
CHANGING DOD ACQUISITION SYSTEM

- Do More For Less, With Less
- Modeling & Simulation
 - SBA-Simulation Based Acquisition
 - HLA-High Level Architecture
 - DIS-Distributed Interactive Simulation
- Common Shared Knowledge Bases
 - Navy - Synthetic Battlespace
 - Army - Virtual Proving Ground
 - AF - JMASS

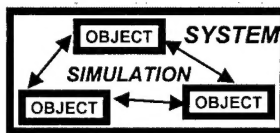
Major Range Test Facility Bases (MRTFB's)



CHANGING TEST PARADIGMS



Greatly Reduce Testing



Evaluate Systems Not Components

ISTF BENEFITS TO RFW

- Secure-SCI Level "War Reserve Modes"
- Complex, Realistic Environments
 - Live, Virtual, Constructive & Distributive
 - Flexible, Adaptive
- Can be Low-Cost Compared to Flight/Ground test and Exercises
- Integrated into DOD High Level Architecture for Acquisition support

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Lets start with a Macroscopic view of ISTF's

1) We are all feeling the crunch of the changing DOD Acquisition system. More for less, consolidation, restructuring, BRAC's, new initiatives and focuses. The situation is very dynamic.

One Place there has been considerable growth is Modeling and Simulation. One way DOD is restructuring acquisition is through M&S initiatives such as Simulation Based Acquisition, High Level Architecture and Distributed Interactive Simulation. These Three initiatives are the Framework for the future of Modeling and Simulation.

Another result will be common shared knowledge bases. Each service is taking a different approach because their mission is different, and DOD allows each service some flexibility. But, the goal is a single integrated M&S system by the year 2010.

2) Next, MFTFB's are merging into a single distributive interactive M&S network. With many ISTF's of varying complexity, each with its own inherently unique strengths. The four ACRONYMS listed are some of the larger ISTF's which I think can readily support RFW.

3) Changing Test Paradigms, Virtual Prototyping is replacing the current Build-test-fix-build approach with the computer based model-test-model-build approach. In the future you won't even build your system until it has already fought many wars and been maintained and repaired in cyberspace. This will significantly reduce the scope and iterations of testing. For this brief, even more importantly, we no longer evaluate an object as an individual but instead we evaluate the objects impact on the overall system.

4) OK how does this new approach and technology benefit RFW,

First of all we can do secure testing. Pilots can do the Belgrade run in total secrecy and safety "War reserve modes" can be developed and their effectiveness evaluated in complex situations.

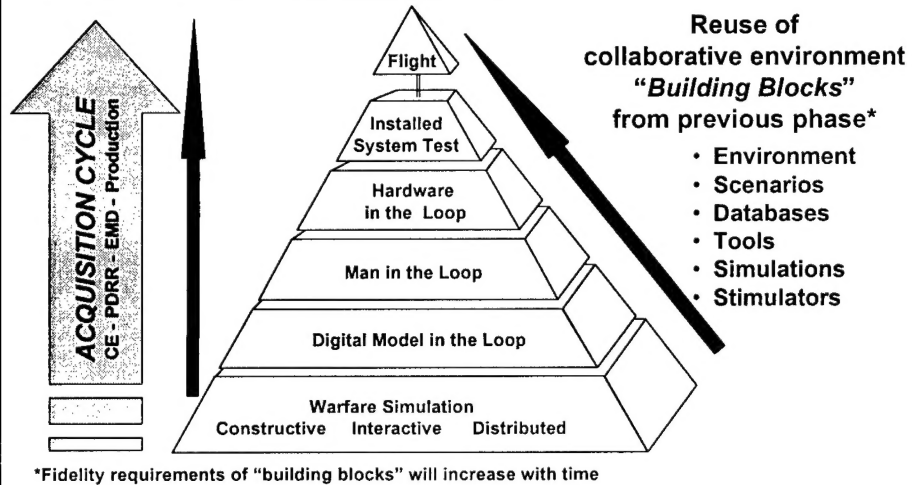
Next, the testing can be both complex and realistic. The players can be any mix of man, machine and software, players can literally be anywhere on earth.

Also, its as real as you want it to be , And it can still be cheaper than flying because when your finished you have a recording which you can edit, improve and playback over and over

Finally, It plugs back into that Common shared knowledge base I mentioned earlier



SBA Strategy



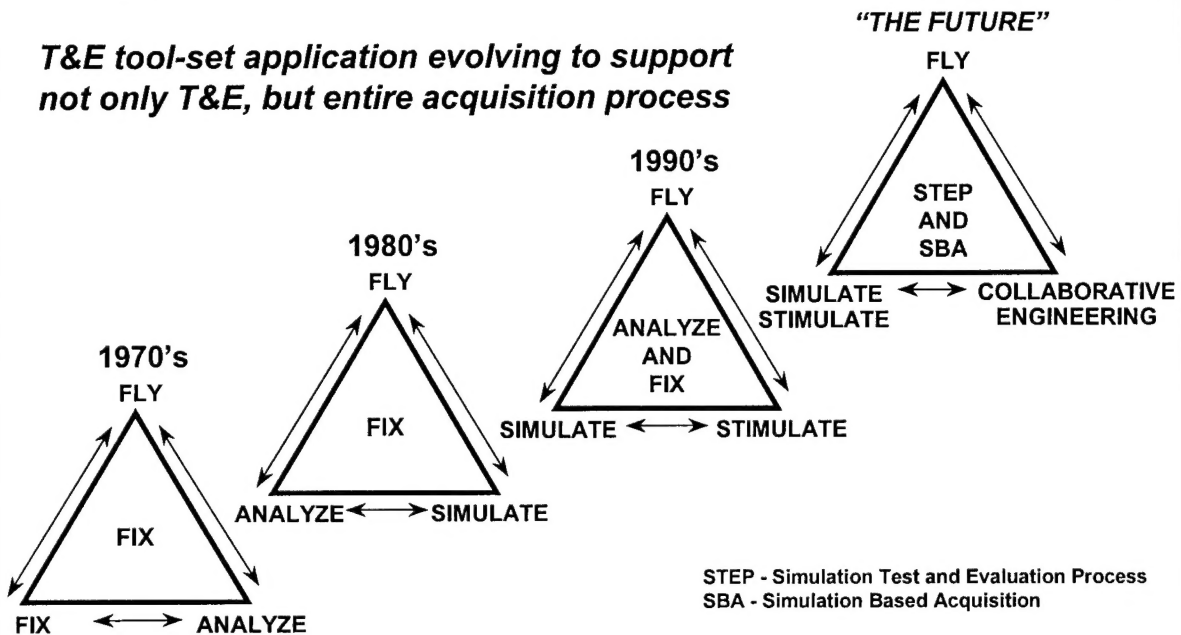
*Fidelity requirements of "building blocks" will increase with time

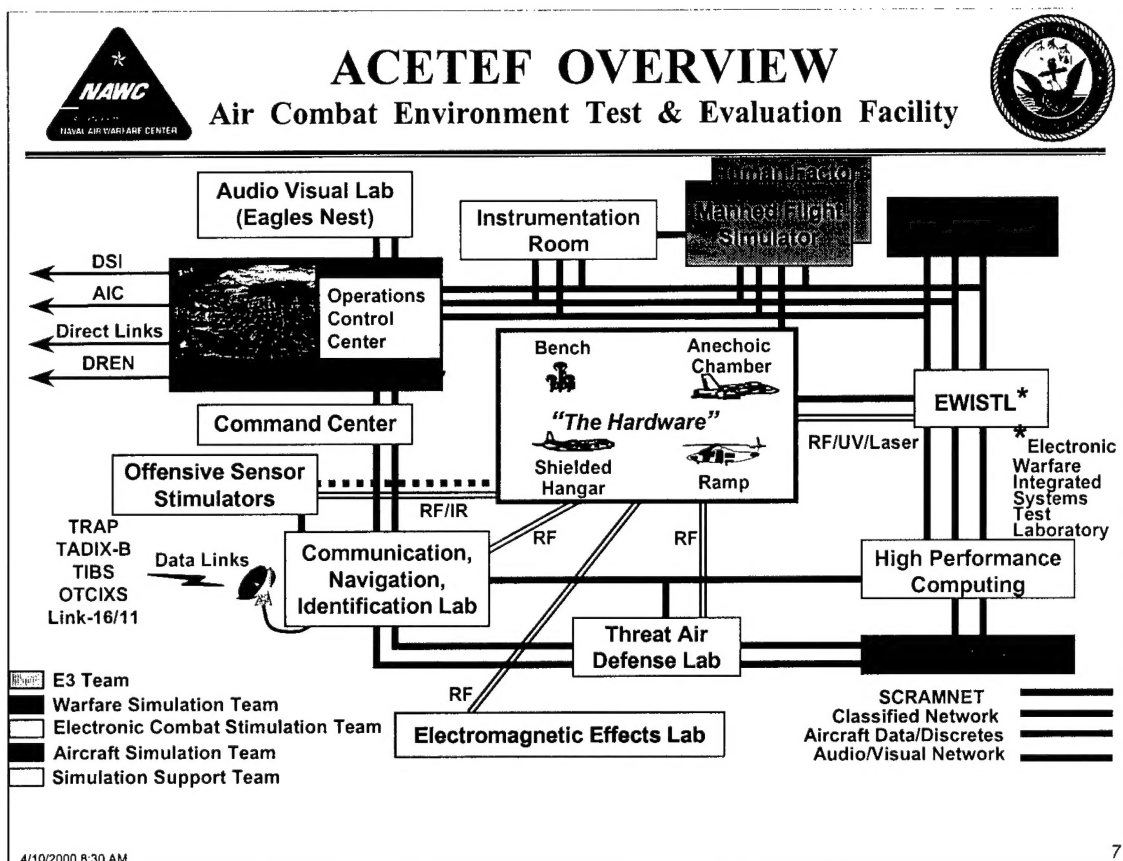


T&E “Tool-Set” Evolution



T&E tool-set application evolving to support not only T&E, but entire acquisition process





Lets quickly look at a typical large-scale ISTF. This particular one is the Air Combat Environment Test and Evaluation Facility or ACETEF. Each Block is a separate laboratory.

We'll start with The E3 Team in Grey. Notice that it is not integrated into ACETEF like the other capabilities. The reason will become apparent later. Most ISTF's consider E3 to be that friendly system RF clutter generated to increase realism. But, Patuxent River's charter is maritime focus, and because of the Navy's intense shipboard RF environment our sources are very powerful, and arguably just as effective as RFW at bringing down aircraft.

Next is the Warfare simulation team in red. This is the team that builds and runs the simulation

In green is the various Electronic Combat team members, this is a very extensive capability. The Electronic Combat people use ACETEF more than anyone else.

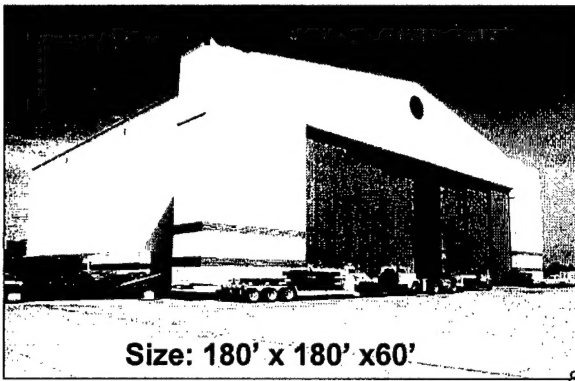
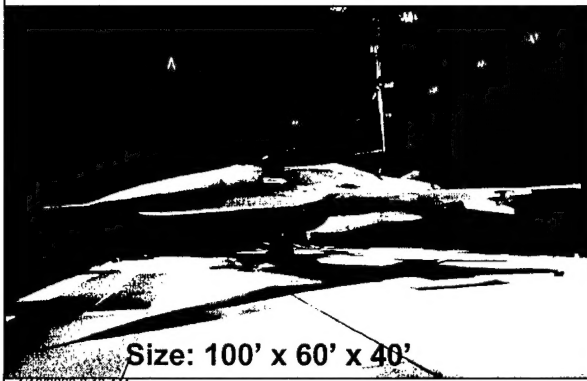
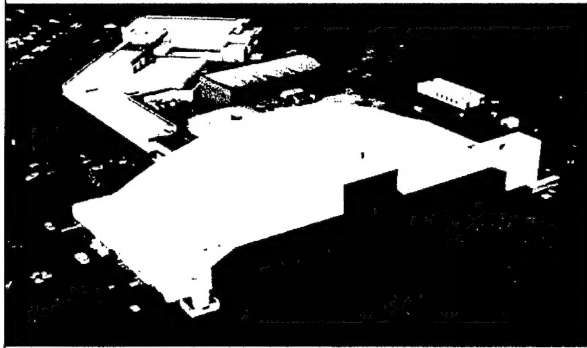
The man flight simulator is shown in orange . This has two motion base simulators and numerous smaller simulators.

The brains behind the operation is shown in yellow. PAX is one of the DOD supercomputer centers. It takes a lot of number crunching to generate the realism needed to make our simulation effective.

In blue you see the test volumes, that's where our "HARDWARE UNDER TEST" is located



CO-LOCATED TEST AREAS



All facilities in ACETEF are located close to the shielded hangar complex, because, to support real-time simulation, you need short bus distances and high speed links.

The Shielded Hangar is the home to the E3 Division. This hangar was originally built for the spruce goose aircraft at the close of WWII. The Brown Building shown behind the shielded hangar is the Man-Flight-Simulator. The large white building in the back is the laboratory spaces for ACETEF.

Located directly across the apron from the shielded hangar is the outside test area we call the Naval EM Radiation Facility or NERF. The NERF does not have a test object size limitation.

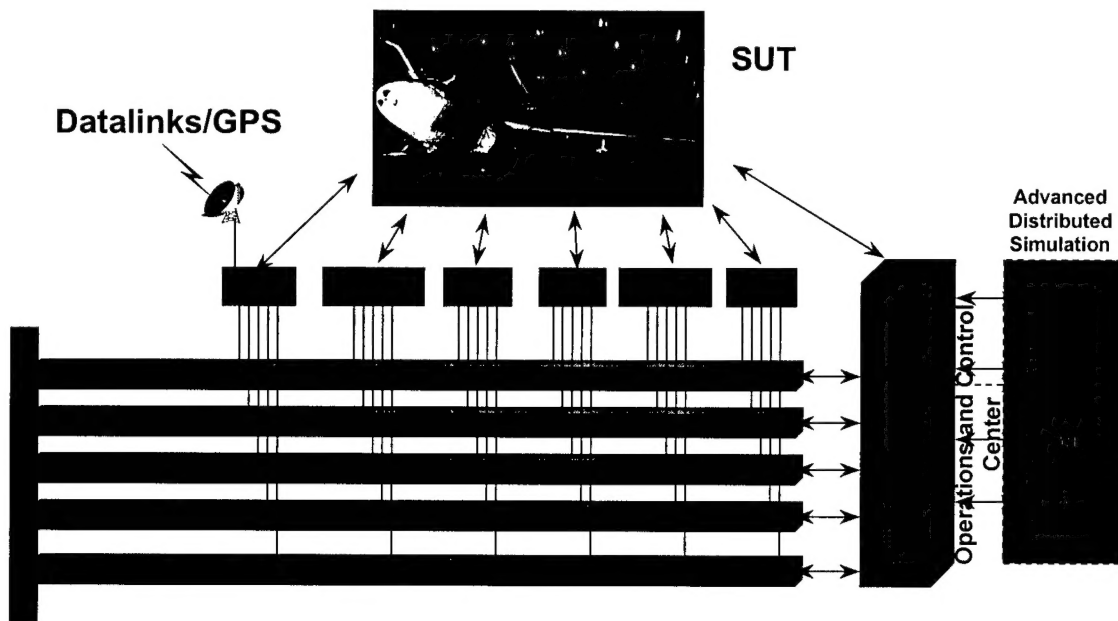
The shielded Hangar nose-bay is home to the small anechoic chamber. It is capable of holding aircraft up to the size of the F-14 and E-2C.

This shielded Hangar photo is a few years old. The new large anechoic chamber, is located to the right of the hangar. This chamber is capable holding a 707 sized Aircraft or several smaller aircraft. It will begin operation later this month.

The Transverse Electromagnetic Mode-Stir (TEMMS) facility is described later in the presentation details. The TEMMS chamber uses many of the principles found in microwave ovens. It is scheduled for Military Construction in 2005 and will be located beside the shielded hangar opposite the large anechoic chamber. The TEMMS will also be capable of housing aircraft of other systems.



Facility Configuration





Manned Flight Simulator



- Two High Fidelity Test Stations
 - 40 Ft Diameter Dome Projection System
 - Wide II Image Projection Sys (200° X 40°)
 - 6 DOF Rediffusion Motion Platform
- Three Low Fidelity Test Stations (200° X 40°)
- CAE Helmet Mounted Display Sys
- General Electric Compu-Scene Imaging Sys
- Linked to Live Test Range

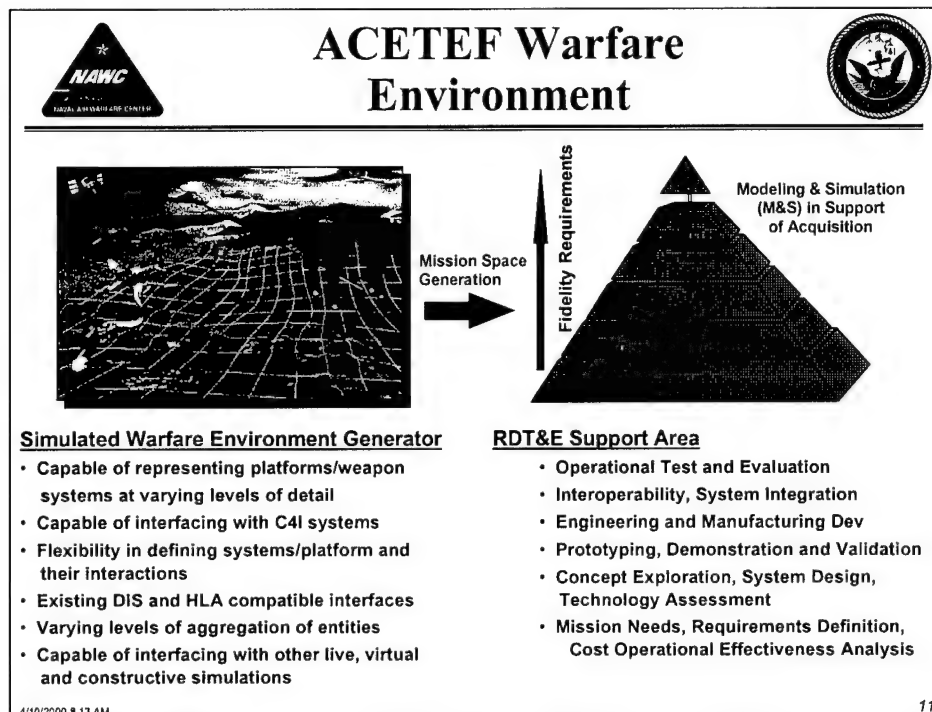


F-18 in Dome

V-22 in Motion Bay



- High Fidelity Cockpits
 - F/A-18 C/D
 - V-22 EMD
 - F-14 D
 - F/A-18 E/F
 - V-22 Prod
 - AH-1W
- Hardware-in-the Loop
 - Flight Control Computer Systems
 - Mission Computers
 - Multi-Function Displays



Lets quickly put the pieces together to show you what we can do in ACETEF.

The Simulated Warfare Environment Generator or SWEG is both the engine and interface for generating the required “synthetic battlespace”, here they also interface with the rest of the DOD .

Since horsepower is always limited, we can represent elements within the system at varying levels of detail depending on their importance. We can interface with real C4I systems. We can adapt and improvise. We use the same tools as other ISTF’s so we can interact distributively all over the world. We can have lots of elements in the simulation and we can use live people or go pure cyberspace

The Pyramid shows the type of M&S performed. The highest level is simulated flight where a pilot sits bobbing and weaving trough a mission inside the domed motion base simulator which is hooked via busses to a real aircraft in the anechoic chamber, where its sensors and systems are being simulated and stimulated with EM signals

As you move down the pyramid The fidelity requirement decreases, many models can be more numerical in nature but the these tools are meant to be building blocks, which can be reused to build the higher level environments.

As far as RDT&E Support areas, It’s as flexible as any capability. Its only weakness is the inability to operate engines inside the chambers, although power and hydraulics can be conditioned. I used to think the limit was a function of your imagination, I’ve decided the limit is a function of Money.



Warfare Simulation Lab



Mini-Crewstations



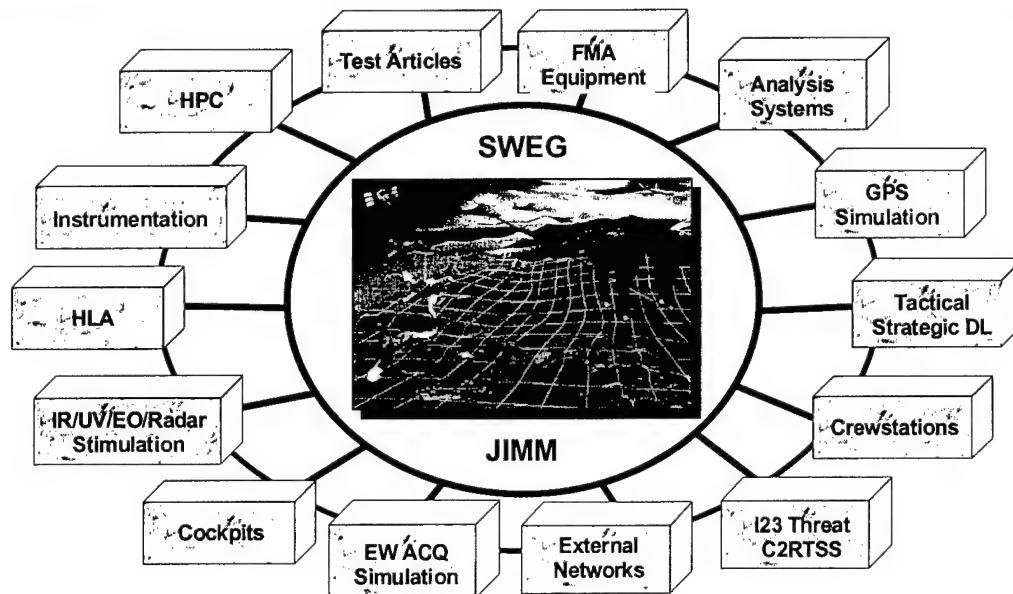
- **Manned Virtual Stations**
 - SGI OTW Image Generation
 - Four Heads Up/Down Stations
 - Ten Heads Up Stations
 - Generic Platform & System Models
 - Attack / Sensors / C2 / Weapons/
Aero / Controls



- **Mission Planning and Rehearsal**
 - JMCIS / TAMPS
 - AFMSS / CIS
 - CLOAR
 - TOPSCENE / Powerscene



Simulated Warfare Environment Generator (SWEG) Joint Interim Mission Model (JIMM)





Operations & Control

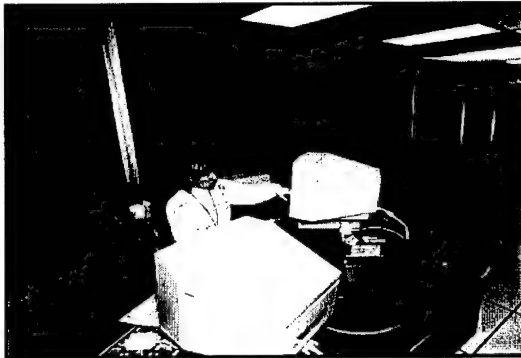


Operations and Control Center

- **High Performance Computing**
 - High Compute and Graphics Engine
 - 106 MIPS R10000 Processors
 - 9 Infinite Reality Engines
 - 36 Gbyte Main Memory
 - 653 Gbyte Disk Storage
- **Facility Instrumentation**
 - Loral 550 Front Ends and Alpha Workstations
- **Internal/External Links**
 - External: DSI, DREN, AIC, Direct Links
 - Internal: Shared Memory, Switched Ethernet/FDDI, Audio, Video
- **Facility Video**
- **Facility Intercom**
- **Master GPS Time Source**

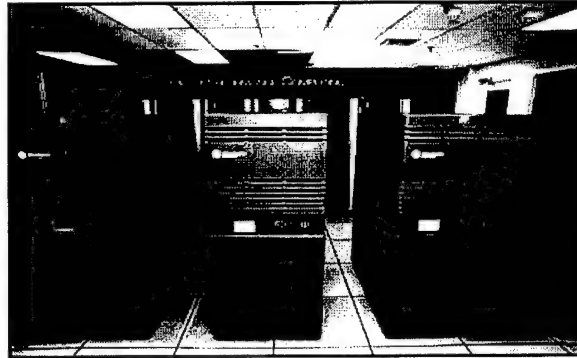


High Performance Computing



HPC Computational Technology Areas

Integrated Modeling & Test (IMT)
Signal/Image Processing
Computational Fluid Dynamics
Computational Electromagnetics
Force Modeling



ACETEF Success Stories

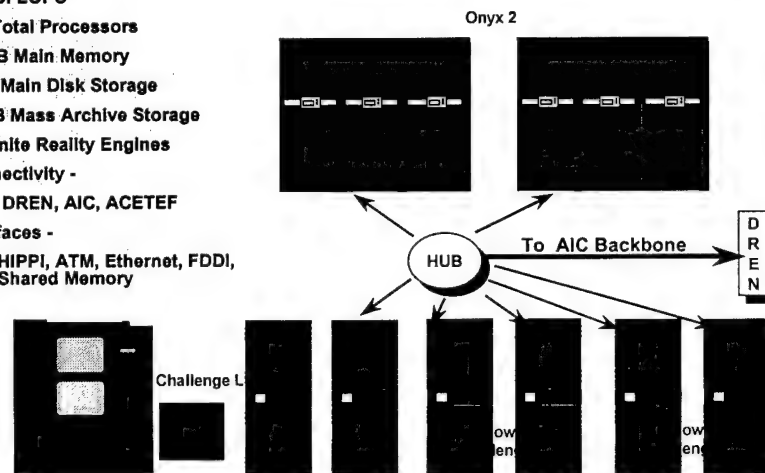
Joint Theater Missile Defense
Inverse Synthetic Aperture Radar Imaging
F/A-18 E/F Flying Qualities
E-2C Phased Array Modeling
"Origin 2000" Power Scene
JSF Force Process Team Simulations



High Performance Computing



- ~42 GFLOPS
- 106 Total Processors
- 36 GB Main Memory
- 1 TB Main Disk Storage
- 12 TB Mass Archive Storage
- 9 Infinite Reality Engines
- Connectivity -
 - DREN, AIC, ACETEF
- Interfaces -
 - HIPPI, ATM, Ethernet, FDDI, Shared Memory





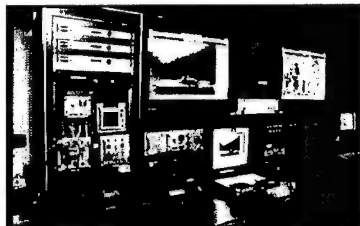
Comm, Nav, Ident Lab



Communications
Environment Simulator (CES)



GPS & Aux Nav Simulator

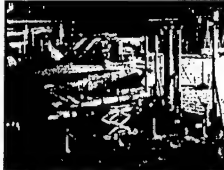


Strategic Data Link Simulator (SDLS)

- Communications Environment Simulator
 - Phase and Amplitude Distribution Ports
 - Number of Simultaneous Emitters: 64 High Fidelity, 128 Background
 - RF Coverage: 500 kHz to 18 Ghz
- Strategic Data Link Simulator (SDLS)
 - OTCIXS/TRAP/TIBS/TADIXS-B
- Data Link Simulator - MLST3
 - Link 4A/Link 11/Link 16 (Link 16 Gateway)
 - LDDS-11 - DTSS-11 (2)
 - Provides Land-line Link-11 (5 site)
- GPS & Aux Nav Simulator
 - 20 Satellite Constellation at RF
 - C/A, P & Y Codes (L1 and L2 Frequencies)
 - Selective Availability/Anti-Spoofing
- Airborne IFF Test System (AITS)



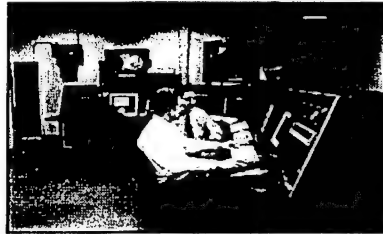
Electronic Warfare Integrated Systems Test Laboratory



Remote Antenna Positioning
System (RAPS)



Advanced Tactical Electronic
Warfare Environment Simulator
(ATEWES)



Electronic Warfare Integrated Systems Test Laboratory

- **ATEWES**

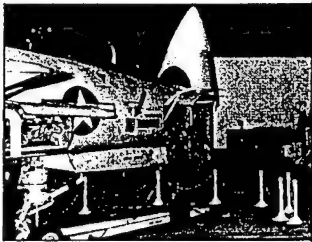
- Phase and Amplitude Distribution Ports
 - 2 Quad - 8 Element Phase AOA
 - 8 Element Amplitude AOA
- Number of Simultaneous Emitters: 1024
- Max Number of Platforms: 255
- Pulse Density: 1Mpps @2% Drop, 4Mpps Max
- RF Coverage: 0.05-18.0 GHz, 32.0-40.0 GHz
- Emitter Library Modes: 7000

- **Remote Antenna Positioning System (RAPS)**

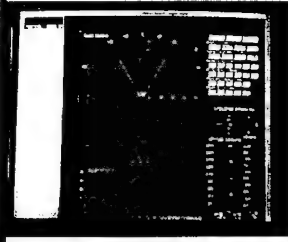
- Two Moving Targets in Two Dimensions
- Mounts Controllable in Azimuth, Elevation and Pointing Angle
- Supports RF, EO, and IR Sources
- Provides 10' x 10' FOV
- Max Slew Rate: 50 Inches/Sec



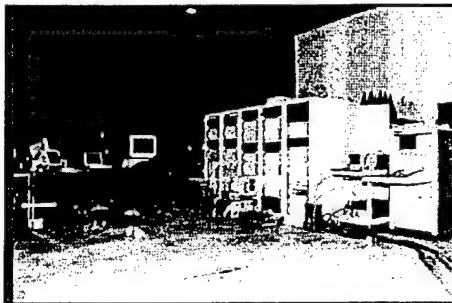
Offensive Sensors



F-14 Tomcat RTS Testing



RTS Display



Radar Target Simulator (RTS)

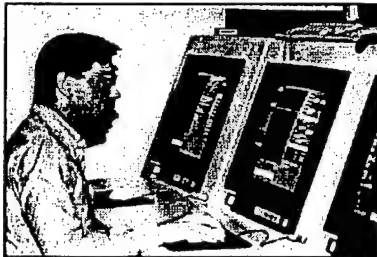
- Radar Target Simulator (RTS) - A/A
 - F/A-18 Interface
 - F-14 D Interface
 - 32 Targets (max 4 in the beam)
 - +ECM, Scenario Driven
- Dynamic Infra-Red Point Source Simulator
 - Two IR point source targets
 - 8 - 12 mm region
 - Independent Position, motion, and intensity target control



Threat Air Defense Lab



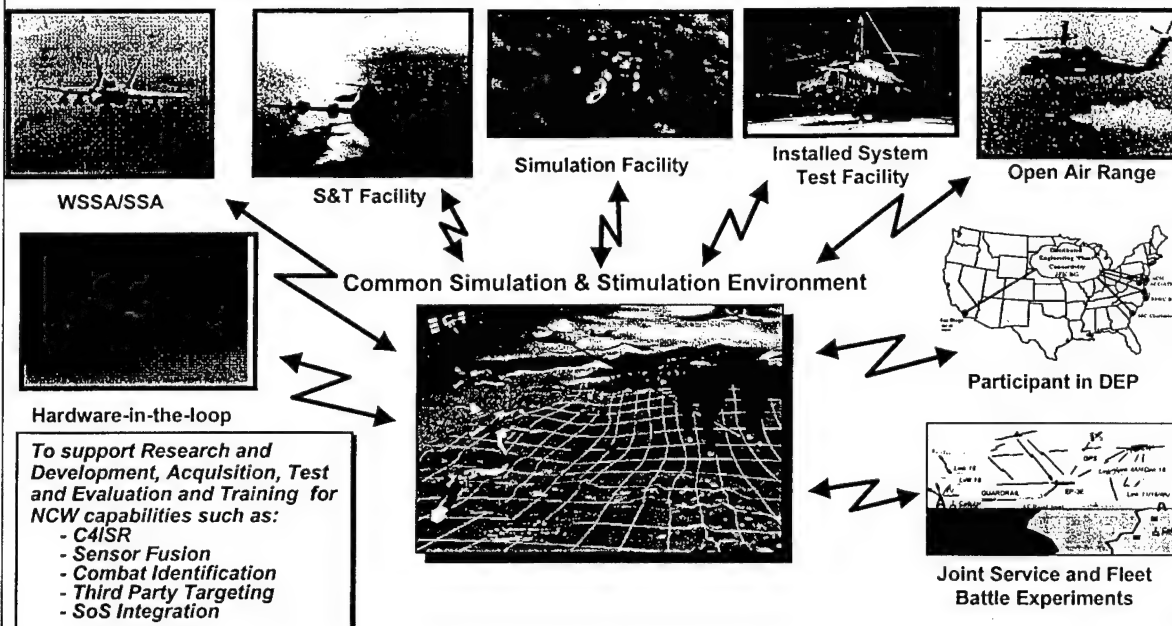
TADL Displays



- SAM Simulation System (I-23)
 - Frequency Range: X-Band
 - Closed Loop Threat Systems
 - Man-in-the-Loop
 - Seeker-in-the-Loop
 - Open Air Range Correlated Equipment
 - Validated Radar and Missile Flyout Model
- EW Acquisition System (EW ACQ)
 - Frequency Range: 800Mhz - 3Ghz
 - Closed Loop Early Warning Radars
 - Man-in-the-Loop
 - Simulates up to 3 RED Systems
 - Provides Handoff to I-23
 - Low Band Threats IOC FY98

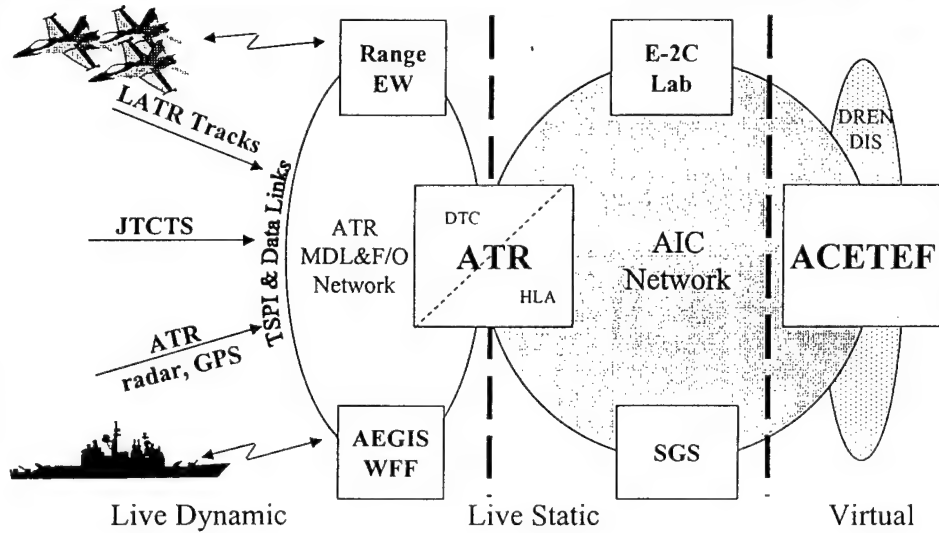


Integrated Capabilities to Support Program Requirements



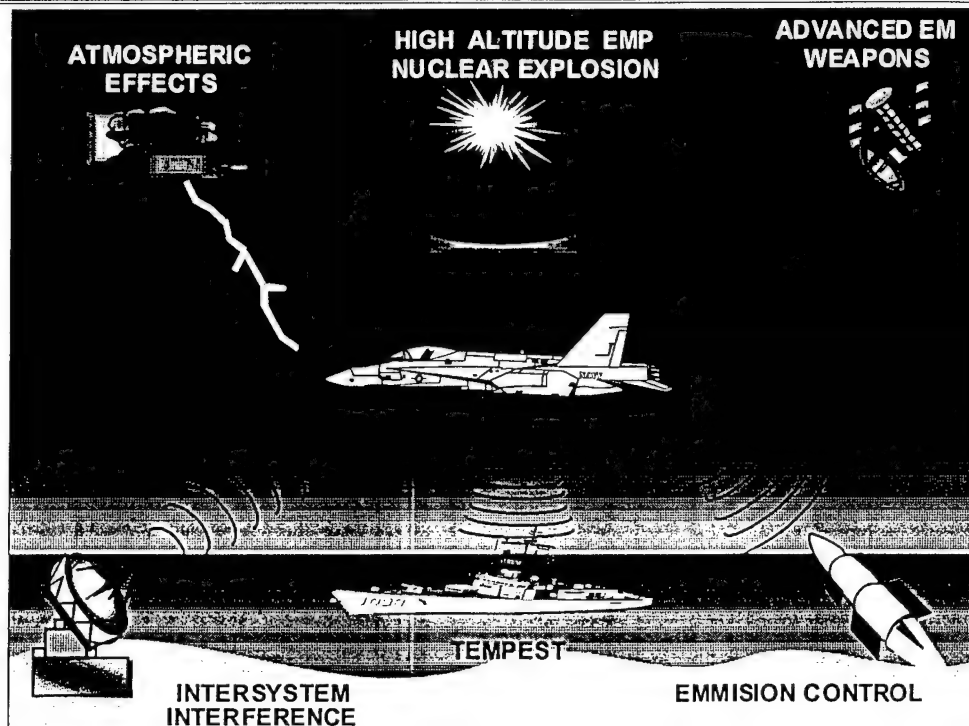


Open Air / Model & Simulation Integration





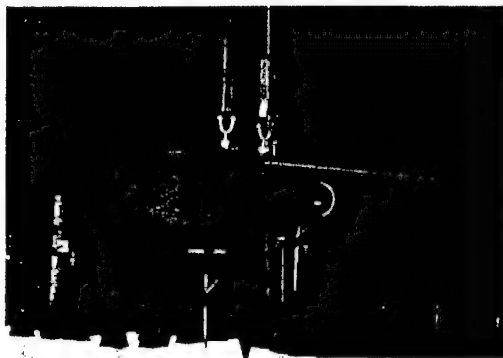
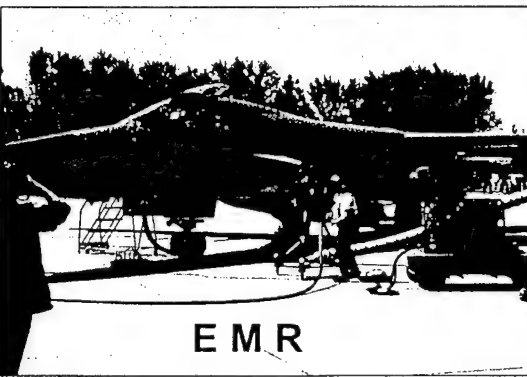
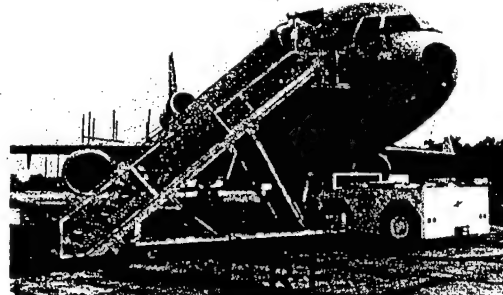
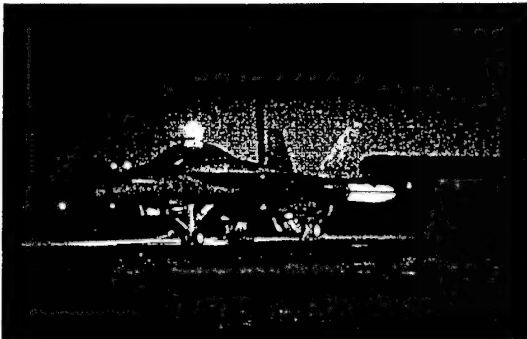
Electromagnetic Environmental Effects (E3)



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E3 - Intersystem EM Interference



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Let's start with E3. The common RF procedures related to RF fratricide and lethality are Intersystem EM Interference. Each of the tests noted HERO, HIRF, EMR and EMV use live Aircraft as the victim and a surrogate threat as the source, but the objectives are slightly different.

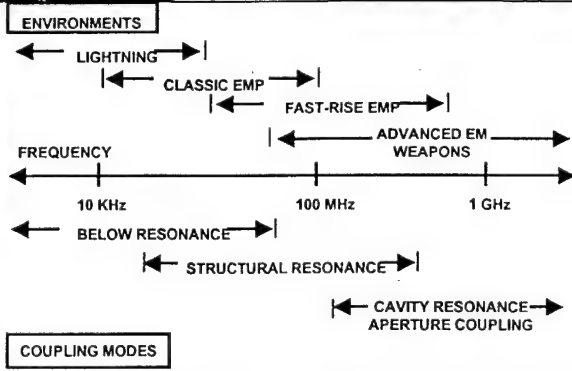
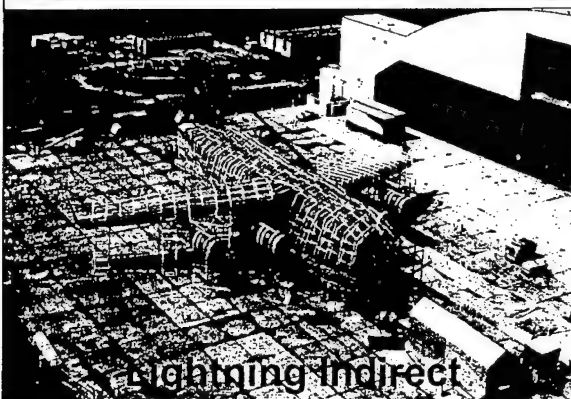
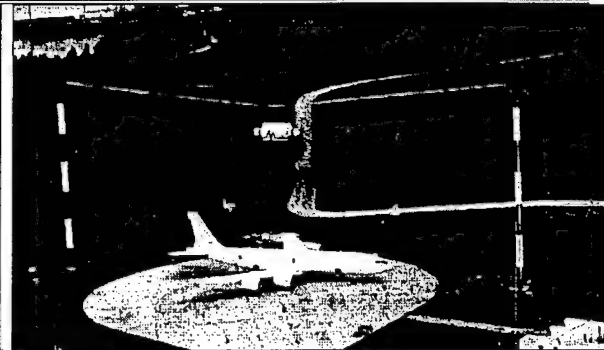
HERO establishes a minimum margin of safety for ordnance and explosives.

HIRF and HERO are civilian and military interpretations of exposure to intense RF environments.

EMV actually sweeps the entire frequency range of interest to search for susceptibilities or vulnerabilities.



E3 - EM Transients

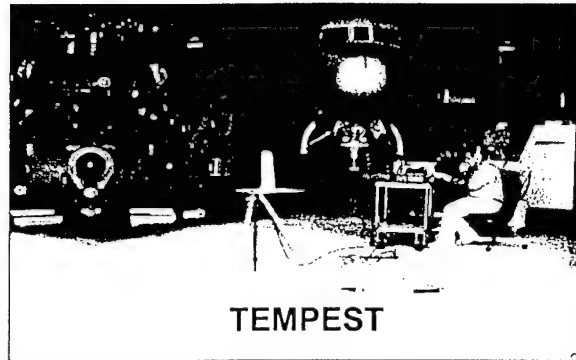
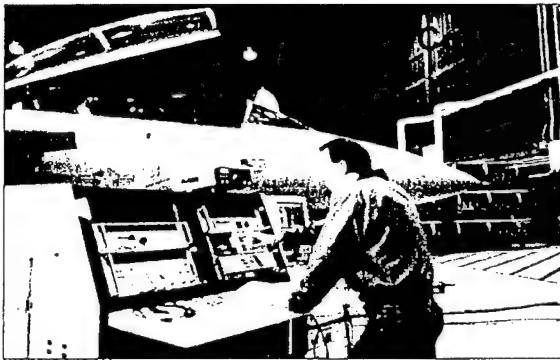
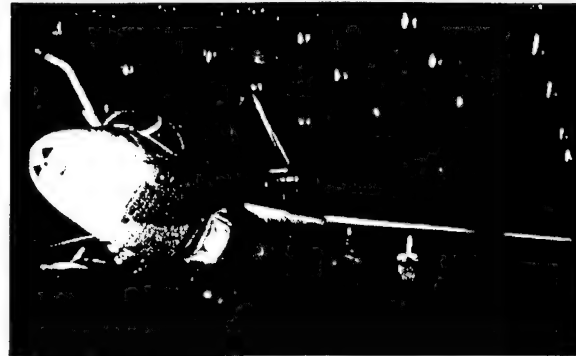


EM TRANSIENT ENVIRONMENTS vs SYSTEM STRESS MECHANISM 35

For Transients we rarely involve ACETEF. Most ACETEF activity in this area is limited to in-flight electrostatic charging and discharging. In case you are not aware, Nuclear EMP is the only RF Weapon include in the STAR's and ORD's of major weapons systems. (we need to fix that)



E3 - EMI, EMC and TEMPEST Testing



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We have separate Facilities to evaluate subsystems and components. The Shielded Hangar and the Anechoic chambers are the location of choice for EMC, emission control, and TEMPEST testing.



ISTF RFW Scenarios



Scenario	Info. Warfare Role	RFW area	ISTF Area(s)	Simulation Complexity
1	Electronic Attack	Lethality	EW Offensive Sensors - E3	HIGH ????
		Fratricide	E3 Intrasytem EMC	LOW
2	Electronic Protection	Susceptibility (Reduce P_{hit})	EW Countermeasures	HIGH
		Vulnerability (Reduce $P_{kill/hit}$)	E3 Intersystem EMC	LOW
3	Electronic Systems	Intelligence Threat Warning	E3-EMC, Avionics Performance: ESM, CNI, Etc.	HIGH

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For our RFW Scenarios in an ISTF we have conveniently coded blue for friendly emitters, red for hostile emitters, and black for our friends in the intelligence community.

Looking at the blue scenario, we assume the platform is hosting a powerful on-board RFW emitter. It could be for self-protect or SEAD - it doesn't really matter. For on-board emitters a side issue of any lethality assessment is fratricide. In my experience, if a program decided to evaluate lethality and fratricide independently I would be comfortable. If you can fire your weapon without harming yourself, and you know you can hit what you aim at, you should be OK. As to the level of simulation for lethality I am genuinely in a quandary as to what complexity level is required, but I know the EW team would want high fidelity so I'll agree. For fratricide, low fidelity is fine.

For the Red scenario, it is also convenient to divide the RFW area into two issues. The first is susceptibility, but its not classic EW susceptibility such as signature reduction or low side lobes, it's the ability of the system to prevent incident radiation from entering the system. These are active RF defensive features such as filtering, blinking or other ECM system self-protect features. The other part of the problem becomes, did any of the RF that got into your system degrade performance and create potential vulnerability, a classic E3 issue. Its important to note that since the encounter will occur at the speed of light and may not have a threat build-up. Susceptibility and vulnerability are inextricably related. You can't afford defensive system failure through some back-door mechanism. I would not recommend anyone use transfer functions and low-level techniques to determine vulnerability until we are very comfortable, all evaluations should be threat level simulations. Using low -level coupling and direct-drive to correlate to threat level EMP is weak, and for RFW assessments the risk will be greater. For susceptibility reduction, a high simulation complexity is desirable. Once again E3 does not demand high simulation complexity

The last scenario is the most complex. For signal detection, and sensor fusion issues; the degree of realism must be extremely high because you might be looking for a weak distant signal buried in a cluttered environment. The number of ISTF participants is high and Simulation Complexity should be very high. The nice thing about ISTF's is you can also reduce the simulation participants to zero for calibration purposes. Or add, remove, and modify entities as required



Issues Associated With Integrating RFW into ISTF's



- Although Ideal for Classified Evaluations, ISTF's are also Valuable for Mission / Tactics / Interoperability Evaluation.
- No Problems Supporting RFW.
 - Assumes Threat Availability
 - Source Safety Issues
- Inadequate Threat Definition Prevents Test Technology Development.
(hurry up and wait . . .)

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What are the general issues associated with performing RFW in an ISTF?

Although classified scenarios and "war reserve modes" are easily evaluated in anechoic chambers, the ISTF will prove a valuable resource for evaluating missions, perfecting tactics, and developing a general understanding of how the RF Weapon affects the overall system interoperability issue.

As far as supporting RFW in an ISTF there should be no major barriers.....Assuming - you have a threat available, AND its safe Our management frowns on explosive devices in our chambers.

Lastly, In E3 alone we are currently investing over many Millions of dollars in DOD funds for technology development. However comma, we have restructured or delayed all RFW, HPM, UWB related T&E development initiatives because of the lack of threat definition. We have no RFW in our STARS or ORDS and without them we can't compete for funds against others that can show a clear shortfall.

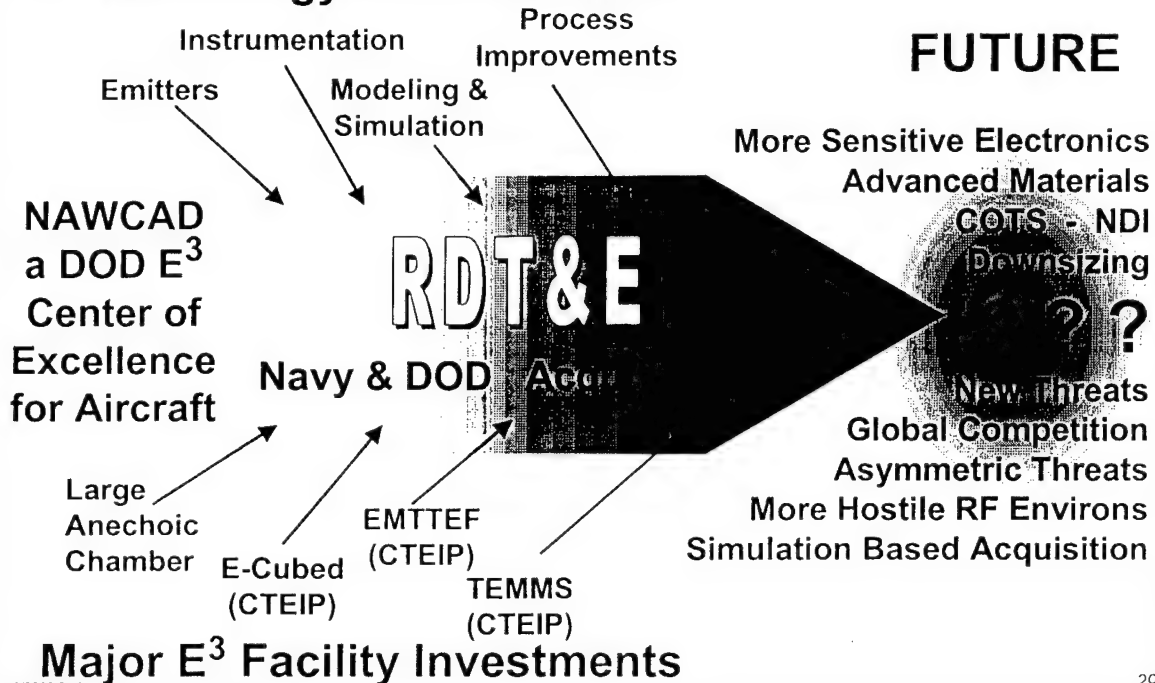
We are in a classic hurry up and wait mode. This is not meant to be a complaint..... its an observation



Examples of how Integrating E3 into ISTF's Supports RFW



E³ Technology Enhancements





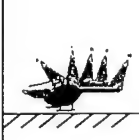
TEMMS

Transverse EM Mode-Stir

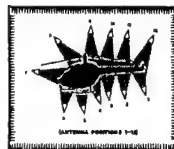


A large shielded enclosure which permits efficient generation Of intense, high-level electric fields for the RF illumination Of large test volumes within a controlled environment.

Test Object Illumination with RF



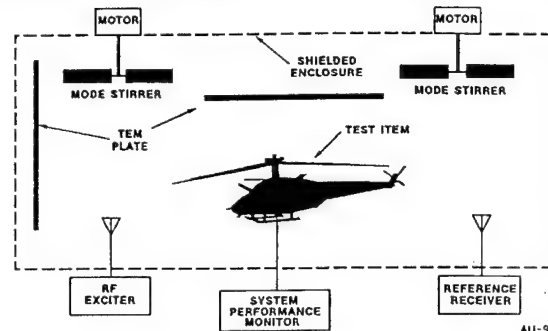
OUTDOOR



ANECHOIC



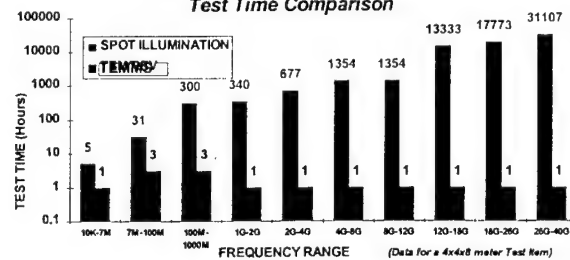
MODE-STIR



AU-9644A

TEMMS vs. Spot Illumination

Test Time Comparison



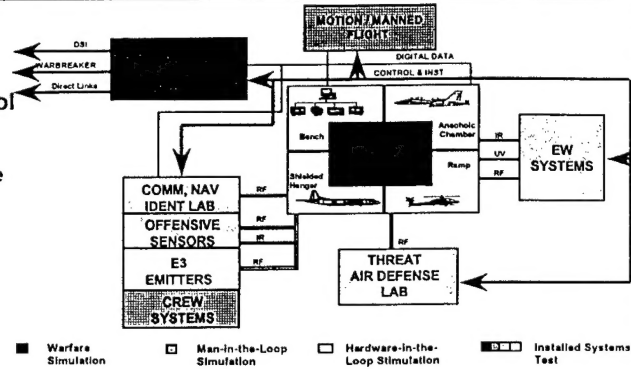


TEMMS Leveraging Technology



Joint Army/Navy Program

- Cost Effective E³ and RF Weapon RDT&E Tool
- Proposing A Large Mode-Stir Facility Capable Of Testing Large Scale Weapon System
- Based on Army's TEM Reverb Design
- Integrate Into Existing ISTF Architecture (ACETEF) at Pax River



Chamber Size (ft): 127 x 113 x 50



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Technology

- Army TEM-Reverb 10% Scale Built/Validated Technology
- Mode-Stir Technology Mature and Rapidly Proliferating
- Efficiencies Higher Than Originally Estimated

Facility (Army)

- Original Design at 65%
- Navy Sponsored SBIR to Review Original Design for Technology Improvements

Location (Navy)

- MILCON P-538, Patuxent River co-located with ACETEF Hgr-144
- EA and Soil Samples Complete (Location is Original Large Anechoic Chamber site)



Summary and Conclusions



- **ISTF's are Becoming a Standard System Evaluation Tool for Mission Effectiveness.**
- **ISTF's Fully Capable and Mature to Support RFW RDTE & Training Requirements.**
- **RFW ISTF Battlespace Complexity will be driven by EW & Intel NOT E3.**

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ISTF are here to stay, they are becoming a standard tool for evaluating the performance of systems in realistic combat scenarios.

The technology and capability associated with ISTF's is mature enough to support most aspects of RFW such as RDT&E and training.

And Finally, as an E3 guy, I'm sorry to report that after evaluating common RFW scenarios, EW and Intel are the areas who will benefit most from the ISTF's capability. E3 does not require high simulation complexity. But, RFW is all about Electromagnetic compatibility so E3 is still a significant part of every evaluation

and that ladies and gentleman concludes my brief.

Thank you



ACETEF POC's



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